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Lake geochemistry in the Kaminak Lake area, District of Keewatin, N. W. T.

R. A. Klassen, Ian Nichol and W. W. Shilts

With 5 figures and 3 tables in the text

Introduction

Geochemical exploration methods require that the medium sampled possesses a diagnostic geochemical feature that can reflect either mineralization or differences in bedrock lithologies. In cases where glacially transported overburden is sampled the geochemical data must be interpreted with regard to the provenance and depositional history of the overburden as well as to the influence of the weathering environment. Lack of attention to these aspects has hampered many exploration efforts in areas of glacial terrain.

The Canadian Shield is characterized by an abundance of lakes. As a result, lake sediments have been considered as a possible sample medium on the assumption that the sediments are composites of hydromorphically and mechanically transported materials from within their drainage basins. Work has been carried out in the western Arctic by Allan (1971) and Allan et al. (1973) in western Newfoundland by Davenport et al. (1975), and in northwestern Ontario by Coker & Nichol (1975), with encouraging results.

The present study is an investigation of the nature and factors affecting metal dispersion in lake sediments in the Kaminak Lake area, District of Keewatin, N. W. T. as a basis for evaluating the potential of lake sediment geochemistry in reconnaissance exploration in this area. This paper presents the salient features of the limnological and trace metal data that are apparent in the preliminary results.

Description of area

The Kaminak Lake area is between longitudes 94°00′ and 96°00′ W and latitudes 62°00′ and 62°30′ N and lies within the Rankin Inlet-Ennadai Archean greenstone belt (Fig. 1). Massive Cu-Zn and Cu-Ni sulphide occurrences within metavolcanics are known in the region and are thought to have considerable economic potential. The study area lies within the tundra, 150 km north of the tree line, and is characterized physiographically by low relief, broad, low hills and numerous northwest to southeast orientated lakes. Surficial deposits are primarily till, marine reworked till, and marine silty-sand. The area is underlain by continuous permafrost with the depth to the permafrost table varying from 15 to 200 cm. Patterned ground features, such as mud boils, frost polygons, and nearshore lacustrine rib and furrow patterns (Shilts & Dean 1975), are common.

The Kaminak Lake area experiences continental Arctic to Sub-Arctic climatic conditions, mean monthly air temperatures ranging from — 30 to + 15 °C. The total annual precipitation is approximately 15—20 cm, rain and snow equivalent. The lakes freeze over by mid October and are ice-free by early July. Ice forms to thicknesses of 2.0 ± m (Bilello 1961). Air temperatures during the 1973 field season were abnormally high. Precipitation was low, and the study lakes were up to 2 m lower than their maximum levels.

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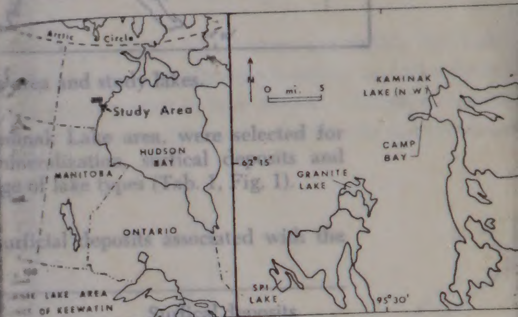

Fig. 1. Location of the Kaminak Lake are

Seven areas in five large lakes within the Kamin investigation on the basis of varying bedrock, mine morphology of the lake basins so as to provide a range c

Tab. 1. Summary of bedrock, mineralization and surfi study lakes.

Lake	Bedrock type (Davidson 1969)	Mineralizati
Spi	Felsic to intermediate volcanics	massive Cu-Zn
Granite	Granitic intrusive	none known
Camp Bay	Intermediate to mafic metavolcanics and sediments	none known
Kaminak Lake (NW)	Intermediate to mafic metavolcanics and sediments, quartz monzonite intrusive	disseminated
Southern	Intermediate to mafic metavolcanics	disseminated
Syenite	Syenite, carbonatite and granitic intrusives	none known

Field and analytical

Grab and core samples of lake sediments were c Petite Ponar grab sampler and a Phleger Corer. Ro ll from active mud boils were collected from th onitored vertically, areally, and with time for vari ygen, and conductivity using a Martek II Water Q

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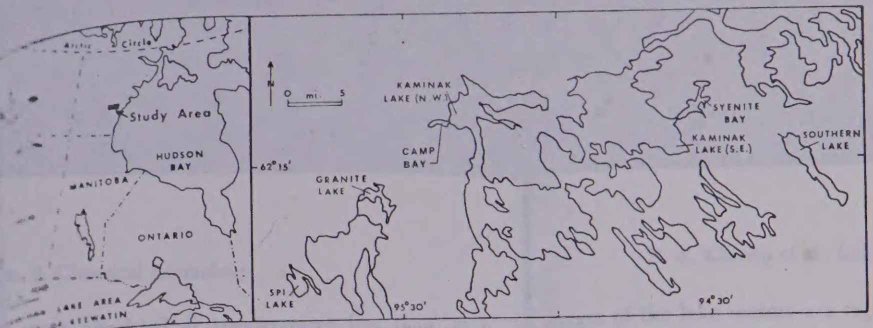

Fig. 1. Location of the Kaminak Lake area and study lakes.

Seven areas in five large lakes within the Kaminak Lake area, were selected for investigation on the basis of varying bedrock, mineralization, surfical deposits and morphology of the lake basins so as to provide a range of lake types (Tab. 1, Fig. 1).

Tab. 1. Summary of bedrock, mineralization and surficial deposits associated with the study lakes.

Lake	Bedrock type (DAVIDSON 1969)	Mineralization	Surfical deposits (SHILTS & BOYDELL 1974)
Spi	Felsic to intermediate volcanics	massive Cu-Zn	Pink coloured sandy till, prominent outcrop along northeast shore
Granite	Granitic intrusive	none known	Red till, prominent outcrop around lake
Camp Bay	Intermediate to mafic metavolcanics and sediments	none known	Marine and alluvial sediment, till
Kaminak Lake (NW)	Intermediate to mafic metavolcanics and sediments, quartz monzonite intrusive	disseminated Cu-Zn	Marine and alluvial sediment, till. Esker along western shore
Southern	Intermediate to mafic metavolcanics	disseminated Cu-Ni	Till with boulder mantle, ribbed moraine. Esker forms islands in southern, central portions of lake
Syenite	Syenite, carbonatite and granitic intrusives	none known	Red till, extensive outcrop along southern shore

Field and analytical procedures

Grab and core samples of lake sediments were collected from the lake basins using a Petite Ponar grab sampler and a Phleger Corer. Rock chip samples from outcrops and till from active mud boils were collected from the lake margins. Lake waters were monitored vertically, areally, and with time for variations in temperature, pH, dissolved oxygen, and conductivity using a Martek II Water Quality Analyser.

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The grab samples of sediment were air dried at temperatures less than 50 °C, disaggregated, and sieved to minus 210 μ (— 80 #). All samples were digested in acid and the Cu, Zn, Mn, Fe, Ni, Co, Pb and Ag contents estimated by atomic absorption (Instrumentation Laboratories 153). Analytical precision was ± 20 % at the 95 % confidence level using replicate samples and a statistical series (STANTON 1966).

The organic carbon content of the samples was determined using a Leco induction furnace and weight loss on ignition data.

Physical and chemical character of lake waters

Variation of temperature, pH, dissolved oxygen, and conductivity in lake water profiles show that there are no obvious differences between lake waters that are attributable to mineralization (Figs. 2, 3, 4, 5). A comparison of these properties with those of lakes elsewhere in the Shield indicates marked differences (Tab. 2). The data interpretation is at a preliminary stage, and as such only the salient features are noted.

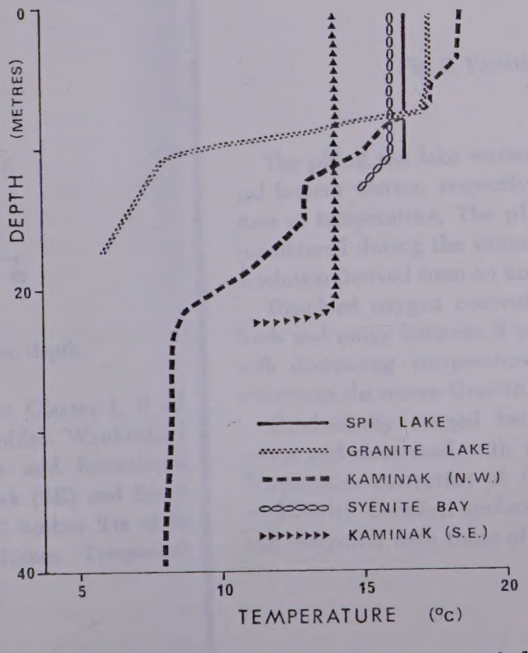

Fig. 2. Variation of temperature of the lake waters, with depth.

The lakes are all temperate, dimictic and represent the Classes I, II and III of HUTCHINSON (1957) as shown by the temperature profiles. Wind-induced internal circulation is very deep during ice-free periods and homothermal conditions were found in four lakes, Spi, Southern, Kaminak (SE) and Syenite Bay. Temperature decreases that ranged from 2° to 6 °C within 2 m of the bottom were observed in Southern and Kaminak (S. E.) Lakes. Temperature

changes of the lake waters are rapid; Spi Lake within 14 days after ice breakup and Syenite Bay a 5 day period in late August. Complex stratifica shown by the formation of multiple thermoclines.

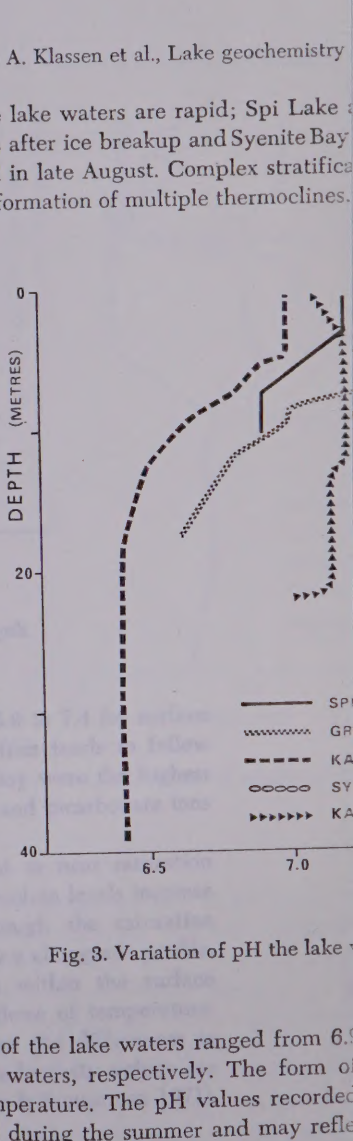

Fig. 3. Variation of pH the lake

The pH of the lake waters ranged from 6. and bottom waters, respectively. The form o those of temperature. The pH values recorde encountered during the summer and may refle in solution derived from an underlying carbona

Dissolved oxygen contents of the surface levels and range between 9 and 10 ppm in all with decreasing temperature and increasin percentage decreases. Granite Lake was the onl

Conductivity ranged between 180 and waters and decreased with depth, the profil Temperature correction of the values would conductivity between surface and bottom w high compared with those of other Shield lak

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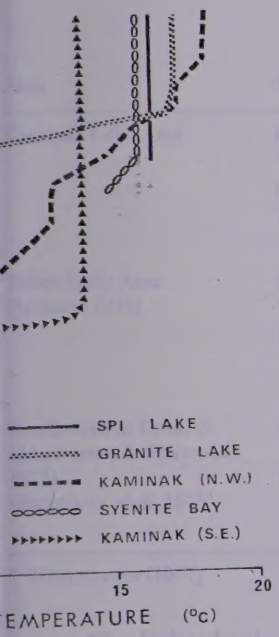

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and Kaminak (S. E.) Lakes. Temperature

Changes of the lake waters are rapid; Spi Lake achieved a temperature of 16 °C within 14 days after ice breakup and Syenite Bay decreased 3 °C throughout, over a 3 day period in late August. Complex stratification of Kaminak (N. W.) Lake is shown by the formation of multiple thermoclines.

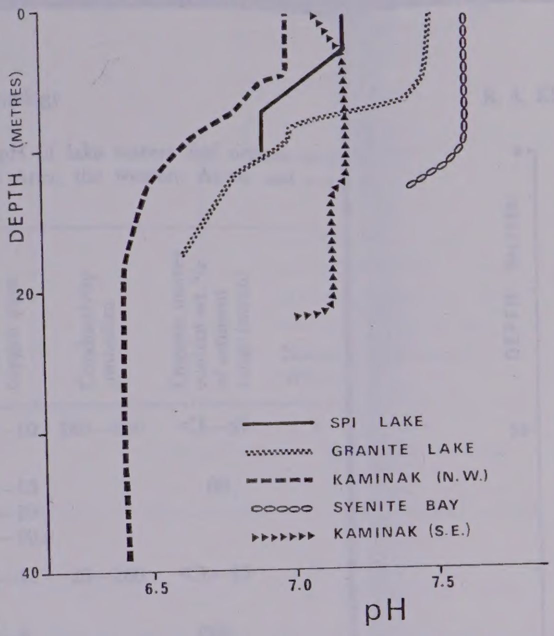

Fig. 3. Variation of pH the lake waters, with depth.

The pH of the lake waters ranged from 6.9 to 7.6 and 5.9 to 7.4 for surface and bottom waters, respectively. The form of the pH profiles tends to follow those of temperature. The pH values recorded in Syenite Bay were the highest encountered during the summer and may reflect carbonate and bicarbonate ions in solution derived from an underlying carbonatite complex.

Dissolved oxygen contents of the surface waters are at or near saturation levels and range between 9 and 10 ppm in all lakes. The absolute levels increase with decreasing temperature and increasing depth, although the saturation percentage decreases. Granite Lake was the only lake to show a clinograde profile.

Conductivity ranged between 180 and 360 μmho/cm within the surface waters and decreased with depth, the profiles following those of temperature. Temperature correction of the values would tend to lessen the differences in conductivity between surface and bottom waters. The conductivity values are high compared with those of other Shield lakes (ARMSTRONG & SCHINDLER 1971).

Tab. 2. A comparison of conductivity, dissolved oxygen and pH of lake waters and organic [illegible] content of associated lake sediments from the Kaminak Lake Area, the western Arctic and [illegible] western Ontario.

Area	Depth	Lake class*	pH	Dissolved oxygen ppm	Conductivity µmho/cm	Organic matter content wt. % of setiment range (mean)	Number of la
Kaminak Lake Area	surface waters		6.9—7.6	8.7—10	180—360	<1—27	6
	bottom waters	I	5.9—7.4	9—10		(6)	
		II	6.4—6.8	9—10			
		III	6.8—7.4	9—10.6			
Yellowknife Area (Jackson 1973)	surface waters		7.0—9.0	8—11	25—160	<1—95	18
	bottom waters	I	6.0—8.0	0.5—8		(35)	
		II	6.0—8.0	2—9			
		III	6.0—8.0	5—10			
Northwestern Ontario (Armstrong & Schindler 1971) (Brunskill et al. 1971)	surface waters		5.6—6.7	8—10	11—61	18—62	
	bottom waters	I		0.1—8.8		(44)	
		II		0—5.0			
		III		3—8.5			

* Hutchinson (1957)

The higher levels in the Kaminak Lake area may be due to salts leached from marine deposits.

Physical nature of lake sediments

The margins of most lakes are characterized by patterned ground features, a sand to boulder covered bottom and a general lack of aquatic plant life (Shilts & Dean 1975). Sediments of the zones that lie away from the lake margins are generally soft, loosely consolidated silts that range in colour from grey (5 Y 5/1)* to dark olive grey (5 Y 3/2) and consist predominantly of quartz and feldspar fragments. The sediments range from 10 to > 70 cm in thickness and may grade over 1 cm into an underlying firm, grey, coarse sand-silt. Pebble to boulder-sized dropstones are common throughout the silt. Silty clays occur locally within lake basins and vary from light yellowish brown (10 YR 6/4) to grey (5 Y 3/2). X-ray radiographs of the cores show that the upper silt material varies from being structurally uniform to being very finely laminated. The cause of the laminations is not known but may be due to iron-manganese coatings as well as textural variations.

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* Munsell Soil Colour Chart.

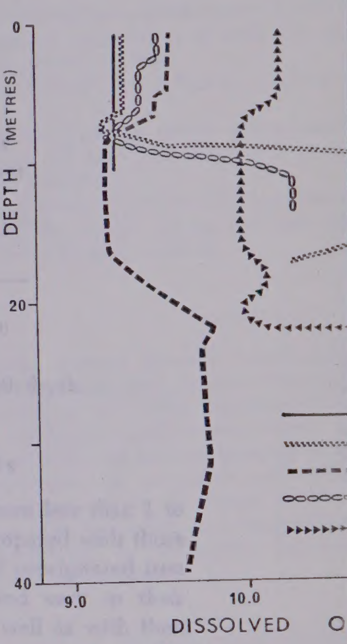

Fig. 4. Variation of dissolved oxygen of th

Chemical nature of la

The organic matter contents of the lake sec
27 % and are generally less than 6 %. These le
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There is no sympathetic variation in trace
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Ci, Zn and Ni show a marked positive corr
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nak Lake Area, the western Arctic a
ntario.

H	Dissolved oxygen ppm	Conductivity µmho/cm	Organic matter content wt. % of setiment range (mean)
-7.6	8.7—10	180—360	<1—27
-7.4	9—10		(6)
-6.8	9—10		
-7.4	9—10.6		
-9.0	8—11	25—160	<1—95
-8.0	0.5—8		(35)
-8.0	2—9		
-8.0	5—10		
-6.7	8—10	11—61	18—62
	0.1—8.8		(44)
	0—5.0		
	3—8.5		

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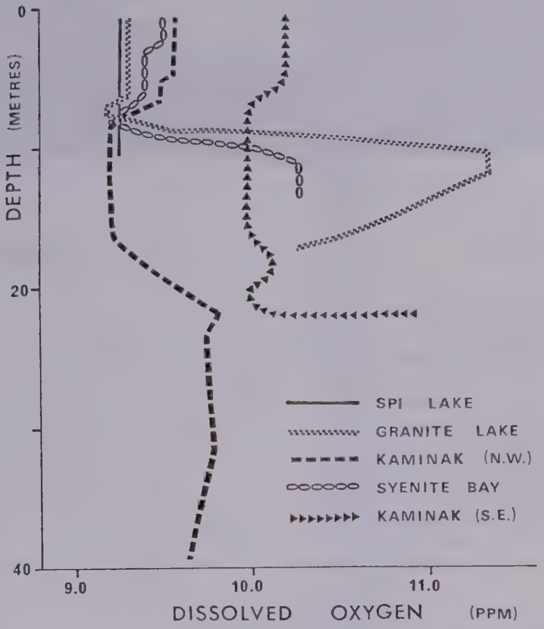

Fig. 4. Variation of dissolved oxygen of the lake waters, with depth.

Chemical nature of lake sediments

The organic matter contents of the lake sediments range from less than 1 to 27 % and are generally less than 6 %. These levels are low compared with those of lakes elsewhere in the Shield (Tab. 2). Horizontal bands of precipitated iron and manganese are distinctive features of the sediments and vary in their character and development within and between the lakes as well as with their host sediment type. The precipitate forms associated with the soft organic silts vary from a red-black surface floc, that may have an underlying 2—3 cm thick zone of finely disseminated manganese particles, to a well-defined 1—4 cm thick dual or triple layered sequence of iron and manganese. This sequence may be repeated lower within the sediment. The inorganic silty clays may have a 0.5 to 1 cm thick cap zone of bright red-orange iron precipitate.

There is no sympathetic variation in trace metal content of lake sediments with their proximity to mineralization. Cu, Zn, Ni, Co, Pb and Ag are low within the minus 210 µ (—80 #) and minus 63 µ (—230 #) fractions of both lake sediments and tills (Tab. 3). The trace metal levels of sediments are, generally, up to two fold higher than the metal content of the corresponding tills.

Cu, Zn and Ni show a marked positive correlation with organic carbon in the −210 µ fraction. This relationship is not as clearly defined for Fe and Mn. Within the clay-sized (— 2 µ) fraction of the sediments preliminary information

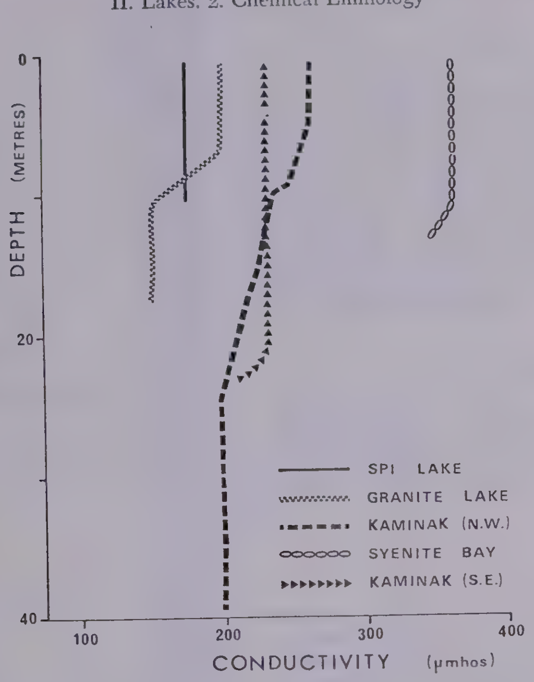

Fig. 5. Variation of conductivity of the lake waters, with depth.

Tab. 3. Range and median values of Cu, Zn, Mn, Fe, Ni, Co and Pb (—210 μ) of sediments and tills.

Sample Type	Trace metal values (ppm)						
	Cu	Zn	Mn	Fe wt. %	Ni	Co	Pb
Sediment	<4—185[1] (12)[2]	<4—200 (40)	50—22000 (200)	<0.1—15 (1.7)	<4—150 (15)	<4—15 (6)	<4—1 (5
Till	<4—55 (10)	<4—100 (30)	50—600 (150)	<0.1—7 (1.4)	<4—55 (10)	<4—17 (5)	<4 (5

[1] Range; [2] Median.

indicates that Cu and Zn are enhanced up to ten fold, and Fe, Mn, Ni and Pb up to two fold, compared with trace metal levels of the coarser fractions. The organic carbon content is not known for the — 2 μ fraction.

The trace metal contents of the surface zones of Fe-Mn precipitate do not differ from those of the underlying sediment.

Conclusions

The lakes of the Kaminak Lake study area have characteristics that differ from those of lakes studies in the western and southern parts of the Canadian Shield. These differences are:

I) the depth and thoroughness of lake water circulati
II) the high degree of oxygenation of both lake w
throughout the summer months,
III) the high conductivities that reflect the high lev
waters,
IV) the very low levels of organic carbon within the se
V) the development of iron and manganese prec
sediment-water interface.

The trace metal levels within the sediment are co
carbon content and the samples do not obviously re
sources in the — 210 μ fraction analysed.

Summary

The relationship between bedrock, overburden
composition is being investigated in five selected
District of Keewatin, N. W. T. The objective of th
factors affecting the dispersion of elements within a
assessing the role of lake sediment geochemistry in r
area. Lakes investigated are associated with diffe
overburden types. Characteristic pH, oxygen, conduc
discussed together with the nature and composition
given of the relationship in composition betwee
sediment in the areas investigated.

Acknowledgem

The investigation comprises part of the prog
geochemistry at Queen's University financed under
between the Geological Survey of Canada and o
constitutes the M. Sc. research topic of R. A. K. Anal
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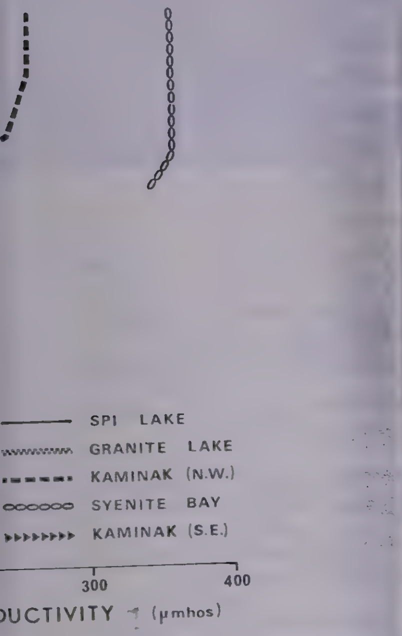

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n, Mn, Fe, Ni, Co and Pb (—210 μ) of
s and tills.

metal values (ppm)

Fe wt. %	Ni	Co	Pb
<0.1—15 (1.7)	<4—150 (15)	<4—15 (6)	<4—
<0.1—7 (1.4)	<4—55 (10)	<4—17 (5)	<4—

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southern parts of the Canadian Shield. Th

the depth and thoroughness of lake water circulation,
the high degree of oxygenation of both lake waters and sediments that persists throughout the summer months,
the high conductivities that reflect the high levels of dissolved solids within the waters,
the very low levels of organic carbon within the sediment and
the development of iron and manganese precipitate bands at and below the sediment-water interface.

The trace metal levels within the sediment are controlled primarily by the organic carbon content and the samples do not obviously reflect the influence of mineralized areas in the — 210 μ fraction analysed.

Summary

The relationship between bedrock, overburden, lake sediment and lake water composition is being investigated in five selected lakes in the Kaminak Lake area, District of Keewatin, N. W. T. The objective of the investigation is to evaluate the factors affecting the dispersion of elements within a permafrost region with a view to assessing the role of lake sediment geochemistry in reconnaissance investigations in this area. Lakes investigated are associated with different bedrock, mineralization and overburden types. Characteristic pH, oxygen, conductivity and temperature profiles are discussed together with the nature and composition of lake sediments. A summary is given of the relationship in composition between bedrock, overburden and lake sediment in the areas investigated.

Acknowledgements

The investigation comprises part of the programme of research in exploration geochemistry at Queen's University financed under the terms of a research agreement between the Geological Survey of Canada and one of us (I. N.). The investigation constitutes the M. Sc. research topic of R. A. K. Analytical advice was provided by J. R. Foster.

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Phosphorus supply in und
Kejimkujik National Park, N

JOSEPH KEREK

With 4 figures and 2 tab

Introducti

The phosphorus loading to mean depth rela
(1968) is based on the view that lakes and their
eutrophic systems, depend on the rate of nutrient
model was used widely to establish the "safe" an
(SCHINDLER & NIGHSWANDER 1970; BRUCE 1973). H
that phosphorus loading due to water inflow sho
Basing his opinion on limited data, KEREKES (
phosphorus concentrations in undisturbed lakes
exceeds an optimum rate. Any further increase
crease in the total phosphorus concentratio
irrespective of the increase in nutrient supply due
(in press) and IMBODEN (1974) proposed that flu
VOLLENWEIDER's model to make its use more uni
state of bodies of water, based on nutrient supply.

In this paper, more evidence is presented to
phosphorus concentration per unit volume repre
relationship that is curvilinear, with the total
flushing rate exceeds an optimum. This evidence
of undisturbed oligotrophic lakes which differ gre

Location and descriptio

The lakes described in this paper lie betwe
and west longitudes 65°09′ and 65°27′ in Kejim
of Nova Scotia, Canada. They are virtually free f
basins lie almost entirely on Devonian granite an
the soils in the Park have developed from glacial
Morphometric features of lakes in Kejimkujik
by KEREKES & SCHWINGHAMER (1973). The lakes
basins studied are between 1 and 4.4 m. They va
24.4 km^2) and and in flushing rate (1 to 418 time
are very common in Atlantic Canada where m
surplus is high. Also drainage systems often cont
ea.

The waters in the Park are extremely dilute
to 24 mg/l. Because of the close proximity of
the dominant ions in precipitation (GORHAM
abundant in the lakes, an example of precipitation
According to KEREKES (1973 b), the Park wate
extremely colored (220 Hazen units). The cle

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AUTHOR
KLASSEN, R.A. et al.

TITLE
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